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High Efficiency Heterojunction Cadmium Sulphide (CdS) Thin Film Solar Cells by Thermal Evaporation Technique

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ABSTRACT

Promising well quality absorber layer of Cadmium Sulphide (CdS) thin film heterojunction solar cells has been prepared by thermal evaporation technique with combination of p-Cu_2S on glass substrate. The Cu_2S layer was produced by vacuum evaporation of a thin layer of CuCl followed by heat treatment. n-CdS / p-Cu_2S solar films are clearly heterojunction cell with CdS having band gap energy 2.42ev and Cu_2S having an energy gap 1.2ev.Band gap energy of Cu_2S layer was responsible for the large photocurrent generation. A typical structure of CdS based heterojunction solar cell is glass/Ag/n-CdS/p- Cu_2S/Al-grid .The prepared films are subjected to X-ray diffraction (XRD), Scanning electron microscopy (SEM), and UV-Vis measurements. X-ray diffraction (XRD) analysis shows the particle size and crystallography of the film. Scanning electron microscopy (SEM) image shows that morphology and texture of the film surface. Then, the optical properties such as absorption, transmittance, and reflection were done by UV-Vis spectral analysis. The photovoltaic properties of n-CdS /p-Cu_2S heterojunction solar cells have been examined after formation. Heat treatment improved the junction formation and as well as efficiency.

Keywords: heterojunction solar cells, p-Cu_2S, thermal evaporation, Cadmium Sulphide.

1. INTRODUCTION

Cadmium Sulphide (CdS) is a promising material for low-cost high efficiency heterojunction thin film solar cells owing to the suitable optical band-gap energy of 2.42 eV coupled with its large absorption coefficient in the order of 10^4 cm^{-1}. CdS is a n-type semiconductor with a direct band gap. It consists of abundant material and it has a potential absorber for thin film solar cells[1-3].

CdS thin films have been grown using various methods such as namely: vacuum evaporation[4], spray paralysis[5], electro deposition[6] and chemical bath deposition[7]. In this work, CdS thin films were prepared by vacuum thermal evaporation of the metallic precursor.

2. EXPERIMENTAL DETAILS

High purity (99.99%) Cadmium Sulphide powder was used for thermal evaporation. Cleaned glass substrates were used for preparation. The glass substrates were cleaned with acetone and rinsed with distilled water. Copper Sulphide powder was placed in molybdenum boat of and heated with high current by energizing transformer. The glass substrate was mounted on a substrate holder. A constant rate of evaporation 10Å/sec was maintained throughout the sample preparation. Rotary drive is employed to maintain uniformity in film thickness. The substrate to source distance was optimized to be at 10.0 cm inside the vacuum chamber. The deposition rate and thickness for all the films were monitored during deposition using quartz crystal monitor.

3. RESULTS AND DISCUSSION

3.1 XRD analysis

The structural analysis of CdS thin films was carried out by using X-ray diffractometer. The X-ray diffraction patterns of the CdS thin films, grown on glass substrates are shown in Figure 1.The XRD analysis shows that the thin films are hexagonal phase with cubic CdS with 380 nm film, indicating that the grain size in this film is larger. The grain size was found to be about 20 nm for the crystallites grown in this direction, or the average radius of the crystallites is about 10 nm. It is necessary to remind by the fact that, lines of smaller intensity give smaller values of d.

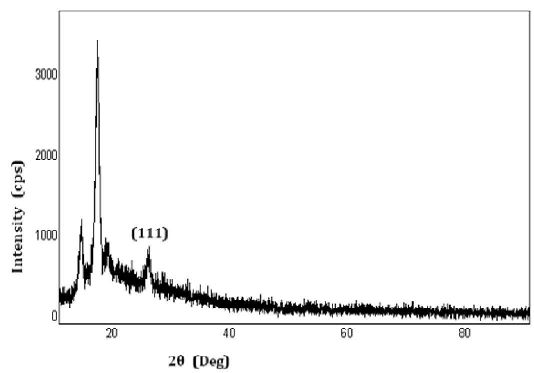

Fig.1. X-ray diffractogram of thermally evaporated CdS thin film

The (111) peak is stronger than other peaks. In general, the preferential orientation of the films is along the (111) direction. The crystallite size in CdSe thin film is evaluated from the intensity peaks of XRD by a Gaussian fit, using Debye-Scherrer formula[8],

$$D = \frac{0.98\,\lambda}{\beta Cos\,\theta} \quad (1)$$

Where, β is the full width at half maximum, **λ** is the wavelength for X-ray used and θ is the Bragg's angle. The lattice parameters, 'a' and 'c' of the unit cell and strain, dislocations were calculated by using the classical relations[9-11].

3.2 Morphological analysis

The SEM micrographs are presented in Fig. 2 (a-b). The grain sizes are spherical in shape and the distribution is closely packed giving rise to little porosity and voids. The averaged crystallite sizes visualized by SEM are 1.6μm for CdS film. The value higher than the grain sizes determined from FWHM of powder diffraction patterns using the Debye-Scherrer equation. Thus, in the former case, agglomerates have been visualized.

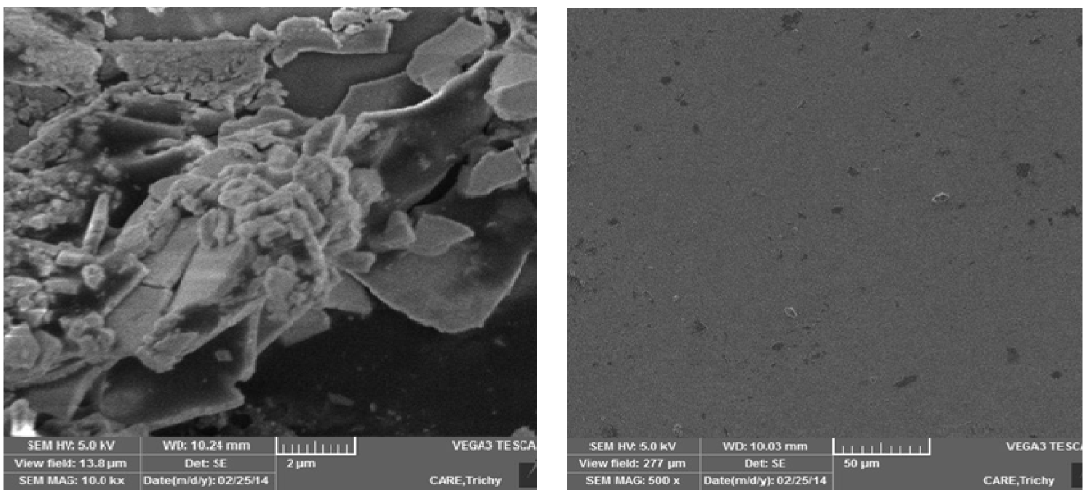

Figure 2: The SEM image of the CdS thin film (a) 2 μm (b) 50 μm

3.3 Optical Properties

The measured absorbance (A) of the film is related to transmittance (T) by

$$A = \log(1/T) = (I_0/I) \quad (1)$$

Where 'I' is the transmitted light and 'Io 'is the incident light. Absorption coefficient of the film decreases at lower thickness and then increases for higher thickness film. The absorption edge increases with increase in thickness, except at higher thickness sample. Hence the film prepared at higher thickness exhibit lower conduction due to higher absorption behavior of the material. The absorption coefficient (α) is related to band gap (Eg) by[12.]

$$\alpha\, h\nu = (h\nu\text{-}Eg)^2$$

for indirect transition (2)

Where, 'ν' is the frequency of the incident light and 'h' is the Planck's constant. Band gap of the material can be determined from the plot of absorption coefficient vs. photon energy curve. Extrapolating the straight line portion of the plot of $(\alpha h\nu)^2$ against hν to the energy axis for zero absorption coefficients,

the indirect band gap 2.16ev of CdS material is determined for different film thicknesses and is reported. It is inferred that band gap decreases with increase in film thickness which may be due to change in the barrier height of the crystalline film[13].

4. CHARACTERIZATION OF THE CELL

For the spray deposited CdS/Cu_2S material, the power conversion efficiency (η) of the device was relatively 3.28%, since the data of photovoltaic parameters such as Jsc, Voc, and FF were obtained.

5. CONCLUSIONS

Well quality, adherent and uniform CdS thin films were grown by the thermal evaporation technique onto glass substrates at vacuum. X-ray diffraction patterns and (SEM) of these films indicated that they have hexagonal structures oriented along the (111) plane. The lattice parameter has been determined and their values are compared with the JCSDS data card. The crystallite size was measured by SEM and by X-ray. The average grain size of films was found to be 1.6 µm which was found to be decreased with the increase of the substrate temperatures. The band gap decreases with increase in film thickness which may be due to change in the barrier height of the crystalline film. The photovoltaic properties of n-CdS /p-Cu_2S heterojunction solar cells have been examined and it reaches 3.28% of efficiency. Heat treatment improved the junction formation and as well as efficiency.

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